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High-resolution 3D subsurface imaging with drone-borne SAR systems

We present preliminary results from a novel drone-borne synthetic aperture radar (SAR) system designed for tomographic imaging of subsurface structures. This system combines advanced flight path strategies—including circular and helical trajectories—with back-projection SAR processing to achieve high-resolution imaging at depth. Operating across three frequency bands (P, L, and C), the radar supports multiple acquisition modes: C-band cross-track interferometry (200 MHz bandwidth), L-band full polarimetry (HH, HV, VH, VV; 150 MHz bandwidth), and P-band interferometry (50 MHz bandwidth). A back-projection algorithm is employed to coherently sum radar returns for each pixel, explicitly accounting for refractive effects that are critical in subsurface imaging.

We demonstrate the system's capabilities using field data collected in Iceland, where tomographic reconstructions successfully revealed high-density material up to a depth of 10 m, consistent with the conduit of a volcanic vent. These results are, to our knowledge, the first demonstration of a multi-band drone SAR system for imaging subsurface features beneath a volcano. The results are highly promising, indicating that this flexible and fully operational system offers a viable new approach for 3D imaging at depth-potentially reaching up to 60 m depending on the underground composition. Beyond volcanology, the system shows strong potential for a range of applications, including detection of buried objects, urban pipe network mapping, and underground water exploration. The drone-based architecture, combined with multi-band and multi-mode SAR capabilities, enables adaptive deployments across diverse terrains and environments, providing a powerful tool for subsurface geophysical investigations.

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